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MEANS FOR REDUCING ELECTRO-MAGNETIC COUPLING

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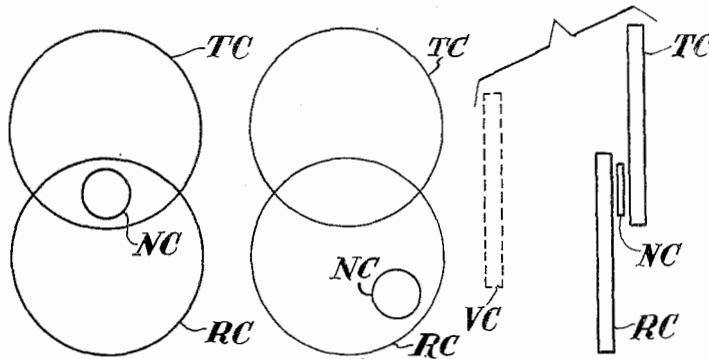


Fig. 1a. Fig. 1c Fig. 1b.

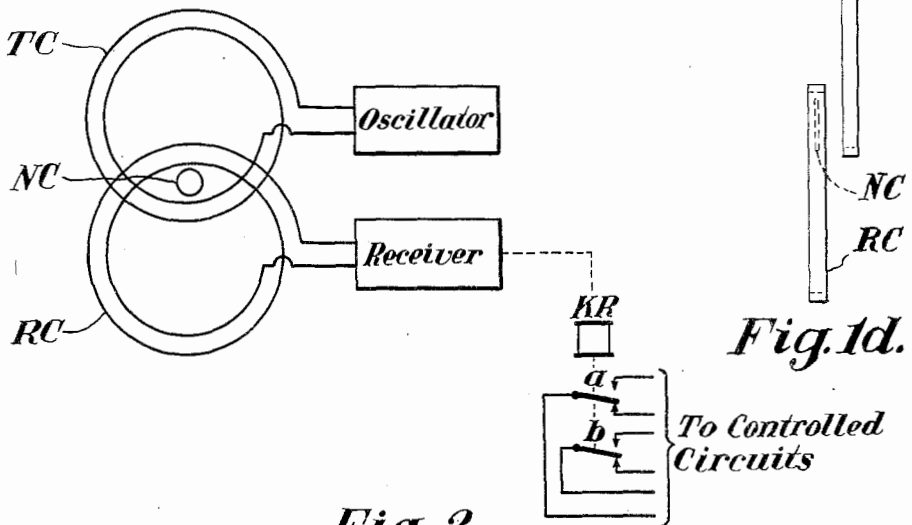


Fig. 2.

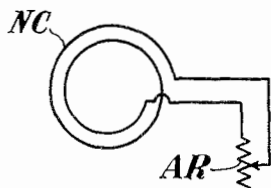


Fig. 3.

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MEANS FOR REDUCING ELECTRO-MAGNETIC
COUPLING

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9 Claims. (Cl. 323—50)

My invention relates to means for reducing electro-magnetic coupling, and particularly to means for reducing the electro-magnetic coupling between air-core coils which are disposed in such manner that the magnetic field set up by current in one coil normally causes a small voltage to be induced in the second coil.

It is well-known in electrical science that the electro-magnetic coupling between two coils which are relatively short in length may be reduced to a minimum by positioning the coils in such manner that their axes are parallel and each axis forms an angle of approximately 54.7° with a line passing through the centers of the coils. Such arrangements are well-known in the art, and are described in detail in the literature, for example, in "Communication Engineering" by W. L. Everitt, published by McGraw-Hill & Co., first edition, 1932, at pages 356 and 504.

However, it has been found that when air-core coils of relatively large diameter are involved, and the coils are arranged so as to overlap one another as a result of the coils being placed in close proximity, it is not possible to reduce the coupling to zero by placing the coils at the so-called "magic angle." In this case, the coupling between the coils is reduced by overlapping the coils so that about 20% of their diameter are overlapped, but it has been found that some coupling usually still exists even with this placement. The cause of this small amount of coupling is not completely understood, but it is believed that the coupling is caused by the phase shift in certain portions of the magnetic flux which links the secondary coil caused by conducting or magnetic material in the vicinity of the coils.

Accordingly it is an object of my invention to provide improved means for reducing the electro-magnetic coupling between two air-core coils mounted in such manner that the coils are overlapped, so that the phase shift of the magnetic flux which causes the coupling between the coils is rendered ineffective.

Another object of my invention is to provide improved means for reducing the magnetic coupling between two adjacent air-core coils.

Other objects of my invention and features of novelty thereof will be apparent from the following description taken in connection with the accompanying drawings.

In practicing my invention, I provide a small short-circuited coil, which is disposed between the two coils with the small coil disposed in the projected area of the secondary coil. The position of the small coil may be varied by suitable mechanical adjustments, and when so varied, a position will be found in which the coupling between the coils is reduced to the minimum possible value which can be ascertained by the usual laboratory instruments, of the order of -50 db.

I shall describe one form of my invention, as employed to reduce the coupling between transmitting and receiving coils of inductive train identification systems, and shall then point out the novel features thereof in claims.

The accompanying drawings show, in schematic form, an arrangement employing my invention in connection

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with an inductive train identification system. In the drawings, Figs. 1a and 1b show two different views of the physical disposition of transmitting and receiving coils for a train identification system, employing a neutralizing coil according to my invention for decreasing the coupling between the transmitting and receiving coils. Fig. 1c is a plan view of one alternative arrangement of the coils. Fig. 1d is a side view showing a second alternative arrangement of the coils. Fig. 2 of the drawings shows, in schematic form, the general arrangement of the apparatus of the inductive train communication system, and Fig. 3 shows a modification of the neutralizing coil which may be employed.

Referring to the drawings, the reference characters TC and RC designate a wayside transmitting coil and a wayside receiving coil, respectively, of an inductive train identification system, of the type shown and described in a copending application for Letters Patent of the United States, Serial No. 213,776, filed on March 3, 1951, by Richard W. Treharne, Jr., for Vehicle Reporting Systems, now Patent No. 2,753,550. The exact form which the apparatus may take is not shown herewith, as it forms no essential part of my invention, and the above-referred to Treharne application describes one arrangement of the system which may be employed with my invention. The over-all features of the invention, as shown in Fig. 2, comprise an oscillator, which is connected to supply relatively high frequency alternating current energy to the transmitting coil TC, and a receiver, which has its input connected to the receiving coil RC. The transmitting coil and the receiving coil each comprise one or more turns of wire wound upon a circular form, to thereby form air-core coils of relatively large diameter and relatively short length. The apparatus is arranged and constructed so that normally a minimum amount of coupling exists between the transmitting and receiving coils, so that very little voltage is induced in the receiving coil. However, when a vehicle-carried coil tuned to the frequency of the oscillator passes the wayside transmitting and receiving coils, as indicated by the dotted outline VC in Fig. 1b, voltage is induced in the receiving coil to cause actuation of the receiver, which results in the operation of a relay, such as the relay KR shown, the contacts *a* and *b* of which serve to control various circuits to indicate the passage of a particular vehicle past the wayside location of the transmitting and receiving coils.

Referring again to Figs. 1a, 1b, 1c and 1d, which indicate the physical appearance of the coils, it will be seen that the transmitting coil TC and receiving coil RC are disposed in such manner that the coils are aligned vertically and overlapped, and the position of the coils is adjusted by suitable mounting means, not shown, so that the flux linkages between the coils are reduced to the minimum possible amount, usually attained when the coils are overlapped to about 20% of their diameters.

In theory, when the coils are arranged in this manner, there should normally be no magnetic coupling from the one coil to the other.

However, it has been found that a small amount of coupling usually exists, presumably due to the geometry of the coils and small amounts of current-carrying material in the coil construction, particularly if the coils are wound on spools made of aluminum or other conducting material for mechanical strength, which material has eddy currents set up therein resulting in a phase shift in the flux which links the two coils. I have found that the introduction of a neutralizing coil, which may consist of a single short-circuited turn of suitable diameter and resistance when properly positioned with respect to the transmitting and receiving coils, will reduce the coupling normally existing between the two coils to an

amount that cannot be detected by the usual laboratory instruments. The neutralizing coil is placed in the manner indicated in the drawings, so that it occupies a position in the projected area of the receiving coil, and is preferably mounted between the transmitting and receiving coils, as shown in Fig. 1b, or in the same plane as one of the two large coils, as shown in Fig. 1c. Suitable mechanical adjustments, not shown, are provided for positioning the neutralizing coil NC at a point within the area so described so as to secure the minimum amount of coupling between the transmitting and receiving coils. In addition to the use of a solid ring of metal for the neutralizing coil, it is also possible to construct the coil in the manner shown in Fig. 3, wherein a coil of relatively few turns has its terminals joined by an adjustable resistor AR, so that the total resistance of the neutralizing coil may be adjusted to produce the desired results.

In the case of coils wound on forms or spools of conducting material, it has been found that the best location for the neutralizing coil is in the projected area of the receiving coil which overlaps the transmitting coil, as shown in Fig. 1a. However, it has been found that in the case of coils wound upon spools or forms of non-conducting material, the coupling between the coil is reduced when the neutralizing coil is located within the projected area of the secondary or receiving coil, but not within the projected area of the overlapped portion of the coils, as shown in Fig. 1d.

A particular advantage obtained by the use of my invention in connection with train identification systems is the increase of sensitivity obtainable. With a reduction in the coupling between the coils, the sensitivity of the receiving apparatus can be increased, thereby permitting a larger spacing between the vehicle-carried coupling coil and the wayside coils, which may be desirable in some instances.

Although I have herein shown the application of a neutralizing means for reducing electro-magnetic coupling as applied to an inductive train identification system, it will be apparent to those skilled in the art that my invention may be as readily applied to other instances in which it is desired to reduce the electromagnetic coupling between two air-core coils which are disposed to have minimum coupling therebetween.

Although I have herein shown and described but one form of apparatus embodying my invention, it is to be understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In combination, a first and a second air-core coil disposed in a parallel relationship to provide an angle of approximately 54.7° between the axis of each coil and a line joining the centers of the coils, and means for reducing the electro-magnetic coupling between said first and said second coil, comprising a neutralizing coil located in the area defined by the normal projected area of one of said coils, and means for adjusting the effective resistance of said neutralizing coil.

2. In combination, a first and a second air-core coil disposed in a parallel relationship to provide an angle of approximately 54.7° between the axes of the coils and a line joining the centers of the coils, and means for reducing the electro-magnetic coupling between said first and said second coil, comprising a neutralizing coil located in the area defined by the overlapping of said first and said second coils, and means for adjusting the effective resistance of said neutralizing coil.

3. In combination with two air-core coils having their diameters in parallel planes and disposed in an overlapping relationship, means for reducing the electro-magnetic coupling between the coils comprising a single-turn short-circuited neutralizing coil disposed in the space defined by the normal projected area of one of the coils,

said neutralizing coil having its diameter in a plane parallel to the planes of said two coils, and means for adjusting the effective resistance of said neutralizing coil.

4. In combination, a first and a second air-core coil disposed in a closely spaced parallel plane relationship, one of the coils having a normal projected area overlapping the other coil by an amount approximately equal to 20% of the coil diameter, and means for reducing the electro-magnetic coupling between said first and said second coil, comprising a low resistance coil disposed between said first and said second coils in the area defined by the overlapping of said first and said second coils, and means for adjusting the effective resistance of said low resistance coil.

5. In combination, a first and a second air-core coil disposed in parallel relationship to provide an angle of approximately 54.7° between the axes of the coils and a line adjoining the centers of the coils, and means for reducing the electro-magnetic coupling between said first and said second coil, comprising a short-circuited neutralizing coil located adjacent said coils and in the area defined by the normal projected area of one of said coils.

6. In combination, a first and a second air-core coil disposed in parallel relationship to provide an angle of approximately 54.7° between the axes of the coils and a line joining the centers of the coils, one of the coils having an area which when normally projected overlaps a portion of the other coil and defines an over-lapped region, and means for reducing the mutual inductance of the coils, comprising a short-circuited neutralizing coil located in said over-lapped region and parallel to the coils.

7. In combination with two air-core coils having substantially equal diameters in adjacent parallel planes, the diameter of one of said coils overlapping the diameter of the other of said coils by 20%, means for reducing the electro-magnetic coupling between the coils comprising a single-turn short-circuited neutralizing coil disposed near said coils and in the space defined by the area of one of the coils projected normal to its plane, said neutralizing coil having its diameter in a plane parallel to the planes of said two coils.

8. In combination with first and second air-core coils having substantially equal diameters disposed in adjacent parallel relationship, said coils overlapping by an amount equal to 20% of one of said diameters, means for reducing the electro-magnetic coupling between the coils comprising a short-circuited neutralizing coil disposed in the space defined by the normal projected area of said first coil and in close proximity to said first coil.

9. In combination, first and second air-core coils having substantially equal diameters and disposed in a closely spaced parallel plane relationship, with the area of said first coil projected on said second coil overlapping the area of said second coil by an amount approximately equal to 20% of the diameter of said second coil, and means for reducing the electro-magnetic coupling between said first and said second coil, comprising a low resistance coil disposed between said first and said second coils in the area defined by the overlapping of said first and said second coils.

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